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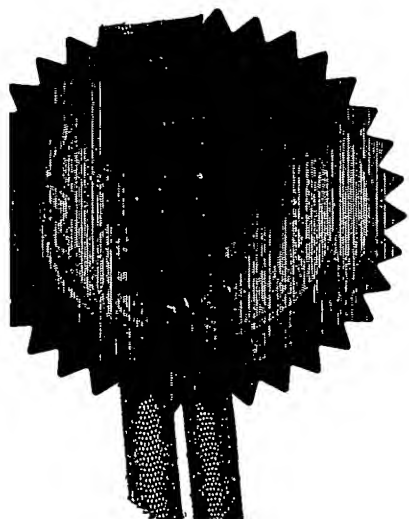
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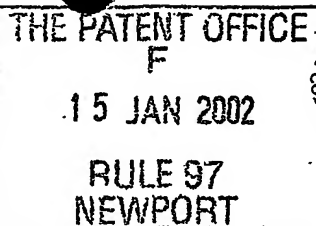


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2. Patent application number

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3. Full name, address and postcode of the or of each applicant (underline all surnames)

University Court of Glasgow Caledonian
University
Cowcaddens Road
GLASGOW
G4 0BA

Patents ADP number (if you know it)

If the applicant is a corporate body, give the country/state of its incorporation

8284481001

4. Title of the invention

Electric motor monitoring system

5. Name of your agent (if you have one)

Kennedys

"Address for service" in the United Kingdom to which all correspondence should be sent (including the postcode)

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Description 22

Claim(s)

Abstract

Drawing(s) 5 + 5 SW

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Statement of inventorship and right to grant of a patent (*Patents Form 7/77*)

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12. Name and daytime telephone number of person to contact in the United Kingdom

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1 Electric Motor Monitoring System

2
3 The present invention relates to the field of monitoring
4 devices for electric motors. In particular, it relates
5 to an arcing event detection device that provides a means
6 for monitoring and recording a variety of electric motor
7 diagnostics.

8
9 Accurate and reliable diagnostic measurements are of
10 paramount importance in the application and control of DC
11 and AC electric motors. The Prior Art teaches of various
12 methods for measuring speed and torque associated with
13 such motors that require the addition of mechanical or
14 electrical components to the motor drive system.

15
16 A summary of conventional speed measurement systems
17 taught in the Prior Art include:

18
19 1) Optical techniques whereby reflected light from
20 rotating components is measured. Such systems require
21 a reflective tape to be placed on the motor shaft.
22 However, within industrial situations maintaining the
23 signal integrity due to the detrimental effects of

1 dirt, loss of connection, shaft vibration etc. becomes
2 highly problematic.

3

4 2) Magnetic Pick-up Devices that employ the Hall effect to
5 measure speed. These devices are susceptible to errors
6 due to magnetic field variations and also require
7 careful positioning on the motor.

8

9 3) Eddy Current Displacement Probes and Variable
10 Reluctance Sensors that both require to be physically
11 mounted close to irregular rotating components such as
12 flats on the shaft or gear teeth. Like the Magnetic
13 Pick-up Devices these probes and sensors require
14 careful positioning and are susceptible to errors due
15 to magnetic field variations around the electric motor.

16

17 4) Hand Held Tachometers that again require physical
18 contact with the rotating shaft of the motor. However,
19 when employed with low power motors the increased
20 torque required during measurement can result in the
21 motor speed being altered.

22

23 Similarly, conventional torque measurement systems taught
24 in the Prior Art include:

25

26 1) Dynamometers, used to measure torque in rotating
27 machinery. In general these devices are impractical to
28 fit to motors once they have been integrated into a
29 particular application.

30

31 2) Measurement of motor current that then allows an
32 estimate of the torque to be calculated by employing
33 motor performance characteristic curves. The major

1 drawback to this technique is that it can be highly
2 inaccurate due to fluctuations in load and speed of
3 rotation.

4

5 3) Measurement of motor back e.m.f. Although the back
6 e.m.f. varies with load it also depends on the motor
7 speed therefore such a method is susceptible to
8 erroneous readings.

9

10 All of the above measurement methods are intrusive and
11 require full access to the motor shaft, the power cables,
12 or the load being driven by the motor. Such measurements
13 often involve the removal of safety guards that can have
14 obvious implications to user safety.

15

16 In addition, industrial plants may require to be stopped
17 in order to allow installation of these speed and torque
18 measurement devices with the effect of increasing the
19 related maintenance costs. Many of these industrial
20 plants employ large numbers of electric motors that
21 require to be monitored. Therefore, it is often
22 impractical to install speed and torque monitoring
23 equipment on all the individual electric motors.

24

25 US Patent No. US 4,577,151 in the name Tanisaka et al.
26 attempts to address some of the problematic features of
27 the Prior Art as highlighted above. This document
28 teaches of a spark monitor device, comprising of an
29 antenna, which is suitable for receiving high frequency
30 noise. The antenna then detects the high frequency noise
31 associated with the sparks generated in a current
32 collector of a rotary electric motor. Monitoring of the
33 electric motor is then achieved by analysing the state of

1 the spark generation on the basis of the product of a
2 peak value of the high frequency noise exceeding a set
3 predetermined value and a time interval during which the
4 peak value exceeds the set predetermined value. This
5 product value is calculated for every arcing event within
6 the motor such that alarm signals are activated in
7 response to each individual arcing event.

8
9 Figure 1 presents a simple two pole DC electric motor 1,
10 that can be tested employing the spark monitor device of
11 Tanisaka et al. The two pole DC electric motor 1 is
12 shown in three different states of operation. From
13 Figures 1(a), (b) and (c) it can be seen that the two
14 pole DC electric motor 1 further comprises a motor field
15 coil 2, two motor brushes 3, four armature coils 4 and a
16 four sector commutator 5.

17
18 Figure 1(d) and (e) show the conditions of the current in
19 one of the armature coils 4 as the commutator 5 passes
20 under a brush 3 from which a constant current I amps.
21 flows. The current flowing through the armature coil 4
22 prior to commutation is $+I/2$ amps (corresponding to
23 Figure 1(a)). During commutation the current in the coil
24 4 is effectively reversed to $-I/2$ amps (corresponding to
25 Figure 1(c)). This process of current reversal takes
26 time T_c seconds. If the current is fully reversed in time
27 T_c then there will be no arcing at the brush contact 3 and
28 the current versus time profile shall be as shown in
29 Figure 1(d).

30
31 However, if the current is not fully reversed during time
32 T_c the commutation time is extended by arcing at the
33 trailing edge of the brush 3, as represented in Figure

1 1(e). This process is known in the art as under
2 commutation. Arcing may also occur if the current
3 reversal is too fast resulting in over-commutation
4 producing arcs at the leading edge of the brush 3.

5

6 The following are a list of factors known to affect or
7 influence the arcing characteristics of the electric
8 motor, namely:

9

10 1) Inherent properties of the brushes. Different
11 brush materials exhibit differing conduction
12 properties and so affect the occurrence of arcing
13 events. Fragmentation of the brush material
14 results in electrical field stress enhancement
15 points that again affect the likelihood of arcing.
16 Sharper edges and greater brush dimensions both
17 increase the chances of such fragmentation. In
18 addition, the inherent shape of the brushes also
19 influences arcing. Sharper edges result in
20 increased current densities and thus an increased
21 probability of the formation of an arc;

22

23 2) The work factor between the brush and the
24 commutator materials also affects the strength of
25 the electric field required to produce arcing.
26 Ionisation voltages, hence arc formation, is found
27 to be material dependent;

28

29 3) Mechanical vibrations within the electric motor
30 affect the charge transfer and the production of
31 fragments from the brush and commutator. Thus
32 mechanical vibrations within the electric motor

1 directly affects the formation of the arcing
2 event;

3
4 4) Inter segment capacitance and inductance affects
5 the flow of charge from the directly connected and
6 non-directly connected segments of the commutator.
7 This factor affects the build up or dissipation of
8 charge within the electric motor thus affecting
9 the possibility of arcing occurring;

10
11 5) The purity and type of gas in the region of the
12 brushes affects the ionisation potential and hence
13 the influence of the arcs produced. In addition
14 any gaseous discharge affects the composition of
15 the gas in the region of the arc, producing
16 charged and excited species that also affects the
17 suppression or regeneration of discharge events;

18
19 6) Aerodynamic effects, such as turbulence around the
20 brush contact area also acts to alter the gas
21 density and hence the affects of the arc
22 discharge;

23
24 7) Metallic components that become etched and
25 fragments that evolve within the motor act to
26 produce field stress enhancement points that also
27 affect the arcing characteristics;

28
29 8) Commutating coil e.m.f. The time T_c during which
30 a coil is short circuited is typically 2ms or
31 less. The rate of current change is therefore
32 very large, typically 100,000 Amps/second. Each
33 armature coil will have an appreciable inductance,

1 and hence during commutation an inductive e.m.f.
2 is generated that acts to oppose the current
3 reversal. This induced e.m.f increases the
4 probability of arcing. Although interpoles or
5 compoles can be employed to reduce the inductive
6 e.m.f. they only act to reduce arcing when the
7 motor is running in the steady state. It is found
8 that motor transients still act to produce
9 significant arcing events.

10
11 Each of the factors outlined above affects the ability of
12 an arc to form, the duration of the arc and the arc
13 intensity. In general these arcing events are rather
14 random in nature, the time duration typically varying
15 between a few microseconds to several milliseconds. The
16 arc is therefore essentially an impulse function with an
17 associated broad band of frequencies in the range 0Hz to
18 1GHz.

19
20 It is these associated frequencies that result in
21 television, radio and general communication interference.
22 Such interference is generally unwanted and the Prior Art
23 teaches of equipment designed at great expense to reduce
24 such arcing events, usually with only limited success.
25 Unlike the teachings of the Prior Art the present
26 invention attempts to utilise these previously
27 undesirable signals in order to provide a means for
28 measuring a range of DC and AC electric motor/machine
29 diagnostics including motor speed and torque.

30
31 The teachings of Tanisaka et al. exhibit certain inherent
32 theoretical and practical problematic features. Most
33 importantly the teachings are limited to the counting of

1 the occurrence of sparking events. The described
2 apparatus does not offer any facilities for relating an
3 arcing event to a particular mechanical or electrical
4 component within the electric motor. Similarly, there is
5 no facility for physically locating the individual arcing
6 events thus, information regarding the deterioration or
7 alignment faults of the component parts of the electric
8 motor cannot be extracted.

9

10 In addition, it can be shown that the relationship
11 between the amplitude of a spark and the applied torque
12 is non linear. The width of the spark can also be shown
13 to be directly proportional to the applied force.
14 Therefore the system as taught by Tanisaka et al. will
15 only work where the electric motor is operating under a
16 constant load. Fluctuations in the load would lead to
17 false alarm signals being generated.

18

19 A third major drawback of the teachings of Tanisaka et al
20 is the fact that in industrial environments, there can be
21 significant levels of background electrical noise
22 generated from a variety of sources e.g. during the
23 opening and closing of relays and electric contacts.
24 Tanisaka's et al method has no way of discriminating
25 between arcing within motors and external noise.
26 Therefore, the presence of such external noise will again
27 result in false alarms.

28

29 The teachings of Tanisaka et al indicate that the
30 sparking on current collectors is an irregular low
31 frequency event. Therefore, their device is limited to
32 use with generators where arcing only occasionally
33 occurs. However, as outlined in detail above, it is now

1 known in the Art that arcing is always present in
2 mechanically commutated machines and so arcing signals
3 are frequently produced as the electric motor operates.
4

5 It is an object of the present invention to provide an
6 electric motor monitoring system for the detection of
7 high frequency arcing events that provides a facility for
8 locating and identifying electrical and mechanical faults
9 within the electric motor.
10

11 It is a further object of the present invention to
12 provide an electric motor monitoring system for the
13 detection of high frequency arcing events that provides a
14 facility for optimising the alignment and monitoring the
15 efficiency of the electrical and mechanical components of
16 the electric motor.
17

18 A yet further object of the present invention is to
19 provide an electric monitoring system for the detection
20 of high frequency arcing events that is capable of
21 suppressing background electrical noise so improving the
22 signal to noise ratio of the detected signals.
23

24 According to a first aspect of the present invention
25 there is provided an electric motor monitoring system
26 comprising an antenna, a data sampling means and a data
27 processing means wherein the electric motor monitoring
28 system provides a diagnostic for monitoring both
29 mechanical and electrical components of the electric
30 motor.
31

1 Most preferably the antenna provides a means for
2 detecting high frequency signals generated by arcing
3 events within the electric motor.

4
5 Preferably the antenna comprises a means for screening
6 background noise so improving the overall signal to noise
7 ratio of the electric motor monitoring system.

8
9 Preferably the antenna further comprises a frequency
10 matching unit, wherein the frequency matching unit allows
11 the antenna to be frequency tuned so as to optimise its
12 operation with the electric motor.

13
14 Optionally the antenna comprises a balanced Faraday
15 screened loop antenna. Alternatively the antenna
16 comprises an unbalanced Faraday screened loop antenna

17
18 Preferably the data sampling means comprises an anti
19 aliasing filter, an analogue to digital converter and a
20 high speed PCI card wherein the data sampling means
21 allows the high frequency signal, over a predetermined
22 length of time, to be captured.

23
24 Preferably the data processing means comprises a computer
25 processor capable of manipulating and storing the sampled
26 data.

27
28 According to a second aspect of the present invention
29 there is provided an antenna for measuring high frequency
30 signals associated with arcing events in an electric
31 motor, comprising a loop and a loop screen, wherein the
32 loop screen shields the loop from background noise thus

1 improving the signal to noise ratio of the signal
2 detected by the antenna.

3

4 Most preferably the loop screen physically covers all but
5 a small detection section of the loop.

6

7 Preferably the antenna further comprises a frequency
8 matching unit, wherein the frequency matching unit allows
9 the antenna to be frequency tuned so as to optimise its
10 operation with the electric motor.

11

12 Preferably the loop comprises a conductor and a screened
13 coaxial cable wherein the conductor is turned back on
14 itself so as to form one or more turns, the end of the
15 conductor cable being attached to the screen of the
16 coaxial cable.

17

18 According to a third aspect of the present invention
19 there is provided a diagnostic method for monitoring both
20 mechanical and electrical components associated with an
21 electric motor comprising:

- 22 1) Detection of high frequency signals associated
23 with arcing events within the electric motor;
- 24 2) Sampling the high frequency signal over a
25 predetermined length of time;
- 26 3) Processing the sampled data so as to provide
27 information regarding the mechanical and
28 electrical components of the electric motor.

29

30 Preferably the diagnostic method provides a means for
31 associating the frequency of the high frequency signal to
32 individual components of the electric motor.

33

1 Most preferably the detection of the high frequency
2 signals employs a non-intrusive antenna.

3

4 Preferably the sampling provides a means for monitoring
5 frequency modulation and amplitude modulation within the
6 high frequency signals.

7

8 Preferably the processing of the sampled data comprises
9 Fast Fourier Transformations of the sampled data so as to
10 convert the sampled data to interpretable frequency
11 spectra.

12

13 Most preferably the interpretable frequency spectra
14 comprise frequency features that can be directly
15 associated with particular mechanical or electrical
16 components of the electric motor.

17

18 Alternatively the processing of the sampled data
19 comprises calculating an average width of the high
20 frequency signals, above a predetermined level, over a
21 number of arcing events.

22

23 Alternatively the processing of the sampled data
24 comprises calculating an average height of the high
25 frequency signals over a number of arcing events.

26

27 Alternatively the processing of the sampled data
28 comprises calculating an average ratio of the width and
29 height of the high frequency signals over a number of
30 arcing events:

31

32 Optionally the diagnostic method for monitoring both
33 mechanical and electrical components associated with an

1 electric motor further comprises the step of self
2 calibration of the diagnostic method.

3

4 Preferably the self calibration of the diagnostic method
5 comprises a current measuring technique involving the
6 steps of:

7 1) Measuring the torque on the electric motor by
8 employing the non-intrusive antenna;

9 2) Measuring directly the current in the electric
10 motor so as to enable the torque on the electric
11 motor to be calculated;

12 3) Taking the difference between the two methods for
13 obtaining the value of the torque on the electric
14 motor so providing a compensation factor; and

15 4) Adding the compensation factor to the non-
16 intrusive antenna method for measuring the torque
17 on the electric motor.

18

19 Embodiments of the present invention will now be
20 described by way of example only with reference to the
21 accompanying figures, in which:

22

23 Figure 1 presents a schematic illustration of a
24 spark monitor device as taught by Tanisaka et al. in
25 conjunction with a two pole DC electric motor;

26

27 Figure 2 presents a schematic illustration of an
28 electric motor monitoring system in accordance with
29 the present invention;

30

31 Figure 3 presents a schematic illustration of a
32 screened loop antenna employed by the electric motor
33 monitoring system of Figure 2;

1
2 Figure 4 presents a measured output signal from the
3 electric motor monitoring system where the system
4 employs:

- 5 a) a commercially available antenna;
6 b) the screened loop antenna of Figure 3.

7
8 Figure 5 schematically presents the electric motor
9 monitoring system employed to measure the speed of
10 the electric motor;

11
12
13 Figure 6 schematically presents the electric motor
14 monitoring system employed to estimate the applied
15 load on the electric motor by evaluating:

- 16 a) the width of the high frequency arcing events;
17 b) the Route Means Square (RMS) or other
18 statistical type measurement of the high
19 frequency arcing events;

20
21 Figure 7 schematically presents the electric motor
22 monitoring system employed to measure frequency
23 modulations or the arcing events within the electric
24 motor;

25
26 Figure 8 schematically presents the electric motor
27 monitoring system employed to measure amplitude
28 modulations of the arcing events within the electric
29 motor;

30
31 Figure 9 schematically presents the electric motor
32 monitoring system employed to measure several of the

1 aforementioned diagnostics of the electric motor
2 simultaneously; and

3

4 Figure 10 presents a schematic illustration of a
5 current measurement technique employed to calibrate
6 the electric motor monitoring system.

7

8 Figure 2 presents a schematic illustration of an electric
9 motor monitoring system, generally depicted at 6. The
10 electric motor monitoring system 6 employs a computer
11 interfacing and data acquisition method to capture and
12 process arcing events within an electric motor 1. The
13 electric motor monitoring system 6 can be seen to
14 comprise a balanced screened loop antenna 7, an anti
15 aliasing filter 8, an analogue to digital signal
16 converter (ADC) 9, a high speed PCI card 10 and a
17 computer processor 11 for analysing the sampled data. In
18 an alternative embodiment the electric motor monitoring
19 system 6 further comprises an amplifier (not shown). The
20 high speed PCI card 10 is capable of capturing and saving
21 several million points of data to the computer processor
22 11 for subsequent analysis. The further processing
23 required depends on what particular parameter requires to
24 be measured, as described in further detail below.

25

26 Detail of the balanced screened loop antenna 7 is
27 provided in Figure 3. The balanced screened loop antenna
28 7 comprises a loop section 12 and a frequency matching
29 tuning unit 13. The loop section 12 is constructed from
30 a conductor 14 and a screened coaxial cable 15. The
31 conductor 14 is arranged such that it loops back on
32 itself with the end being attached to the screen of the
33 coaxial cable 15 at the start of the loop section 12.

1 The screen of the coaxial cable 15 is deployed such that
2 it extends in two directions from the start of the loop
3 section 12 with a small gap being left at the far end.

4
5 Employing the frequency matching tuning unit 13 allows
6 the electric motor monitoring system 6 to be optimised
7 for use with a particular electric motor 1 or to be
8 altered for frequency selectivity for use with multiple
9 electric motors. Optimising the frequency selection of
10 the balanced screened loop antenna 7 for a particular
11 electric motor design and geometry has the advantage of
12 optimising the arcing event signal characteristics for
13 the particular fault conditions as outlined below.

14
15 In an alternative embodiment it is possible to employ an
16 unbalanced screened loop antenna or a multi-turn screened
17 loop antenna (not shown). The multi-turn screened loop
18 antenna comprises a number of screen coiled loops with a
19 small gap in the cable screen being at the furthest point
20 of the coiled loops.

21
22 Figure 4 highlights the significant advantage of
23 employing the balanced screened loop antenna 7 over those
24 previously described in the Prior Art. Antennas employed
25 in the Prior Art are designed to receive continuous
26 broadcast signals. Therefore, employing such an antenna
27 with the present system provides a measured RF signal
28 that is a combination of both the desired electric motor
29 signal and any unwanted broadcast signal as shown in
30 Figure 4(a).

31
32 A further problem of employing the antennas taught in the
33 Prior Art for such a measurement is their susceptibility

1 to ringing when an RF impulse is received. The antenna
2 inductance, stray capacitance and the associated receiver
3 input impedance circuitry create a tuned circuit that can
4 cause prolonged ringing. The duration of the prolonged
5 ringing becomes problematic if the antenna is used to
6 measure the speed of an electric motor (as described
7 below). Ideally it desired that antenna signal
8 oscillations should be completely damped before the next
9 arcing event occurs.

10

11 Employing the balanced screened loop antenna 7
12 significantly reduces these problematic features. As
13 seen in Figure 4(b), the signal to noise ratio of the
14 measured RF signal is greatly improved by employing the
15 balanced screened loop antenna 7. Here the arcing events
16 16, as the commutator 5 crosses the brushes, are clear.
17 There are two very close arcing events 16 due to the
18 arcing on each brush occurring at slightly different
19 times. Thus, as described in the Prior Art, if the
20 number of segments on the commutator 5 is known the speed
21 of the electric motor 1 can be calculated.

22

23 Alternatively, the ADC 9, high speed PCI card 10 and
24 computer processor 11 can be employed to calculate the
25 speed of the electric motor 1. Fast Fourier Transform
26 (FFT) techniques are employed so as to convert the
27 detected arcing events 16 so as to provide information
28 regarding rotational speed. Figure 5 schematically
29 presents the FFT carried out by the electric motor
30 monitoring system 6 with the resultant speed
31 representation depicted at 17.

32

1 Further processing techniques, carried out by the ADC 9,
2 the high speed PCI card 10 and computer processor 11
3 provide estimates of the applied load or torque on the
4 electric motor 1. It is found that a percentage of the
5 detected arcing event signal, above a comparator level,
6 is directly proportional to the applied load or torque.
7 Therefore, by calculating the average width of the arcing
8 event signal, over several thousand arcing events 16,
9 provides a measure of the applied load or torque on the
10 electric motor 1. The relationship between the width of
11 the arcing event 16 and the applied load or torque is
12 presented in Figure 6(a).

13

14 It is also found that there is an inverse proportional
15 relationship between the RMS height of the arcing events
16 16 and the applied load or torque. Thus, the ADC 9, high
17 speed PCI card 10 and computer processor 11 are employed
18 to calculate RMS height so providing a means for plotting
19 the relationship with the applied load or torque, see
20 Figure 6(b).

21

22 In addition to the relationships between the arcing
23 events 16 and the applied load or torque it is found that
24 the ratio of the width to height is sensitive to load or
25 torque variations. Therefore, calculating the width to
26 height ratio provides an ideal diagnostic for monitoring
27 such variations in the applied load or torque.

28

29 The aforementioned techniques for calculating applied
30 load or torque provide ideal means for testing the
31 functionality of suppression of components such as
32 interpoles or compoles (not shown) within the electric
33 motor 1. A failure of one of these components would

1 alter both the height and the width of the arcing event
2 16 and so would show up on the graphs of Figure 6.

3
4 Both the condition of the brushes, commutators and
5 flashover fault conditions, that can result in arcing
6 extending between commutator segments of the electric
7 motor 1, can be monitored using the same techniques.
8 Changes due to degradation on the brushes and the
9 commutators will affect the height and frequency of the
10 arcing event signal and so would again show up on the
11 graphs of Figure 6.

12
13 Employment of the FFT techniques provides a further
14 embodiment for measuring diagnostics of the electric
15 motor 1 as outlined in Figure 7. Using the ADC 9 and the
16 high speed PCI card 10 a frequency modulated data sample
17 18 can be obtained. FFT of this data sample 18 by the
18 computer processor 11 provides a frequency spectrum 19
19 with side bands 20. These frequency side bands 20 are
20 indicative of variations in the speed of the motor 1
21 produced by faults such as slipping belts, eccentric
22 gearing etc.

23
24 The described embodiment of the electric motor monitoring
25 system 6 also provides a means for evaluating possible
26 mechanical eccentricity variations on the axis of
27 rotation of the electric motor 1. This may be carried
28 out both at the installation stage as well as during
29 servicing of the motor 1 so allow the efficiency of the
30 electric motor 1 to be optimised.

31
32 A similar technique is employed to monitor the amplitude
33 modulation of the arcing events 16, as outlined in Figure

1 8. FFT of an amplitude modulated data sample 21 produces
2 a frequency spectrum 22 with side bands 23 that are
3 indicative of friction variations within the motor e.g.
4 within the bearings, in the clutch mechanism, or due to
5 imbalances in the load etc.

6
7 The aforementioned electric motor diagnostics have been
8 described in isolation for clarity purposes. However,
9 due to the nature of FFT it is possible to measure
10 combinations of these diagnostics simultaneously as
11 outlined in Figure 9. Employing appropriate software
12 processing allows different faults known to occur within
13 electric motors 1 to be distinguished e.g. broken
14 brushes, wear in the commutator, excessive vibrations,
15 eccentricity problems etc. Different frequency spectrum
16 components and magnitudes of these components from the
17 captured data sample may be appropriately filtered to
18 isolate the fault condition.

19
20 A further embodiment of the electric motor monitoring
21 system 6 employs a current measuring technique 24, as
22 shown in Figure 10, for calibrating the electric motor
23 monitoring system 6. Calibration employs the RF antenna
24 torque measuring technique (T1) as described in Figure
25 6(a) and the measurement of the current I through the
26 electric motor 1. By multiplying the measured current I
27 by the torque constant K, that is an inherent property of
28 the electric motor 1, an estimate for the applied torque
29 (T2) is obtained. Ideally these two methods should
30 provide the same value for the applied torque. Any
31 difference between these values is indicative of
32 contamination within the motor 1 thus, the offset (T2-T1)

1 can thereafter be added to the T1 torque value to
2 compensate for any contamination.

3

4 The described electric motor monitoring system 6 is an
5 ideal means for testing an electric motor 1 at the end of
6 a manufacturing process. It provides for checking the
7 functionality of the interpoles, decoupling capacitors
8 and for identifying obvious manufacturing faults such as
9 poor connectors.

10

11 The present invention offers several inherent advantages
12 over the Prior Art. It can be employed to measure speed,
13 acceleration and torque of the associated the electric
14 motor 1. Employment of the balanced screened loop
15 antenna 7 significantly improves the signal to noise
16 ratio of the RF detected signals and so provides more
17 accurate readings of these diagnostics.

18

19 A second advantage of the present invention is that the
20 employment of FFT techniques provides a means for
21 measuring and locating both electrical and mechanical
22 faults within the electric motor 1.

23

24 A further advantage of the present invention is that it
25 provides an electric motor monitoring system 6 that
26 provides portable, adjustable and non-intrusive
27 measurement of various diagnostics of the electric motor
28 1. Therefore, the electric motor monitoring system 6
29 does not require the electric motor 1 to be stopped for
30 installation purposes. In addition, where it is required
31 to monitor a large number of electric motors it is
32 possible to employ the same system that can simply be

1. located and frequency matched, in turn, to each
2 individual electric motor.

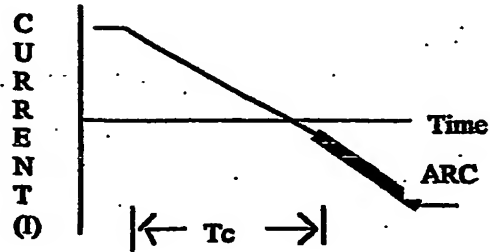
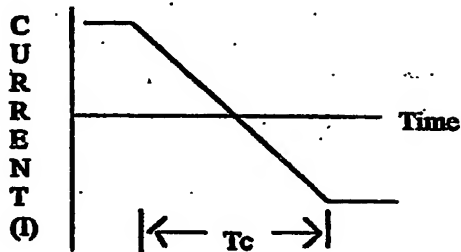
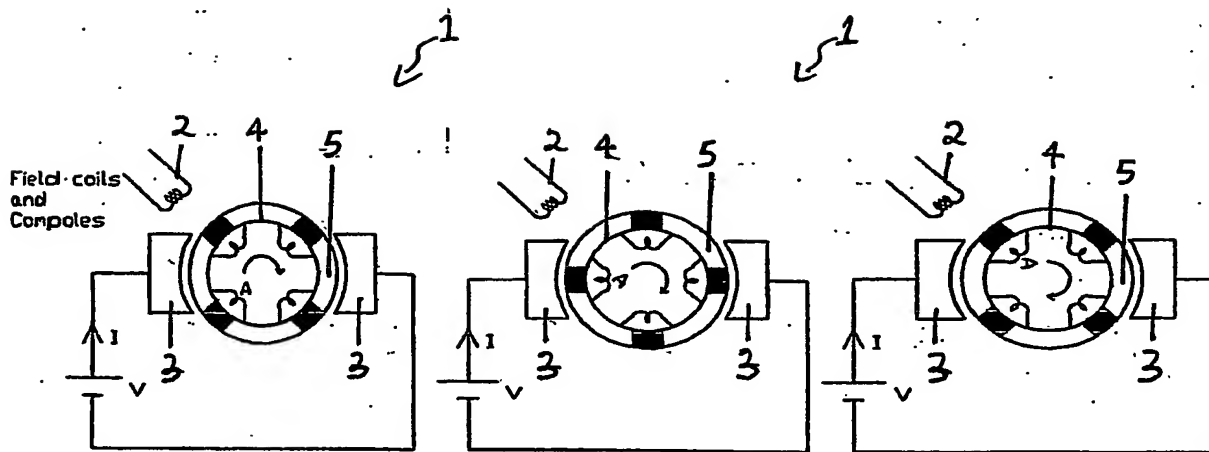
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4 A yet further advantage of the electric motor monitoring
5 system 6 is that when used in conjunction with standard
6 torque measurement techniques it provides a means for
7 self calibration and compensation to take account of
8 contamination within the electric motor 1.

9

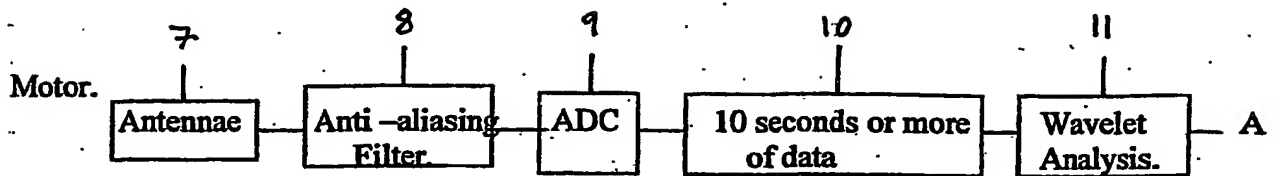
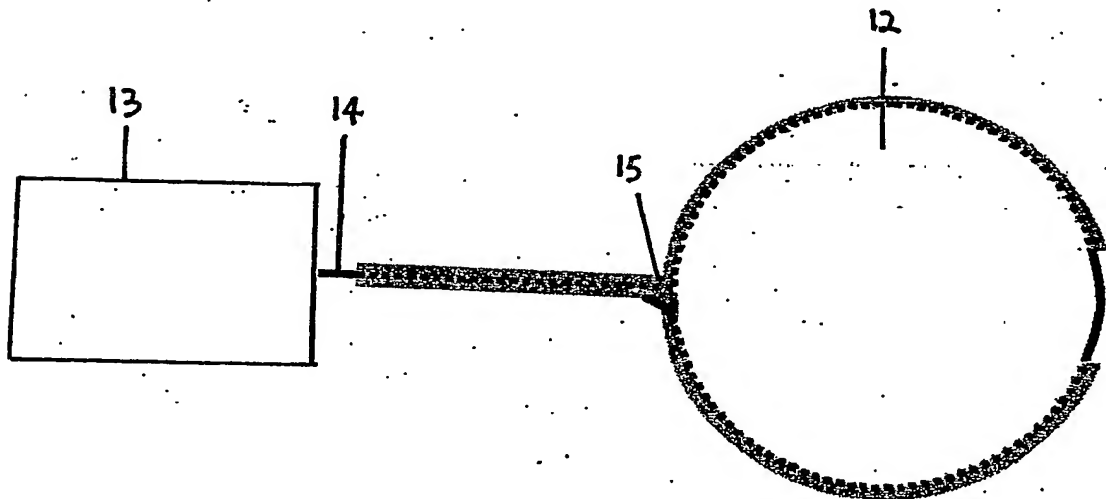
10 Further modifications or improvements may be incorporated
11 without departing from the scope of the invention herein
12 intended.

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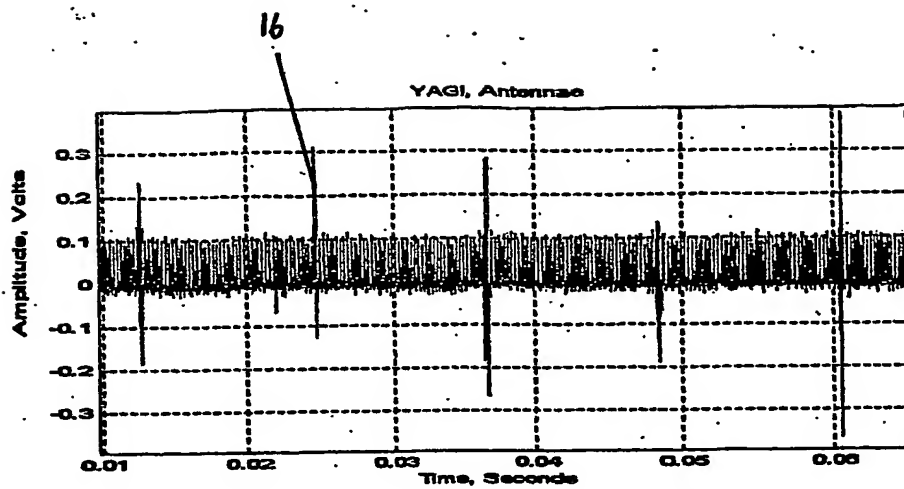


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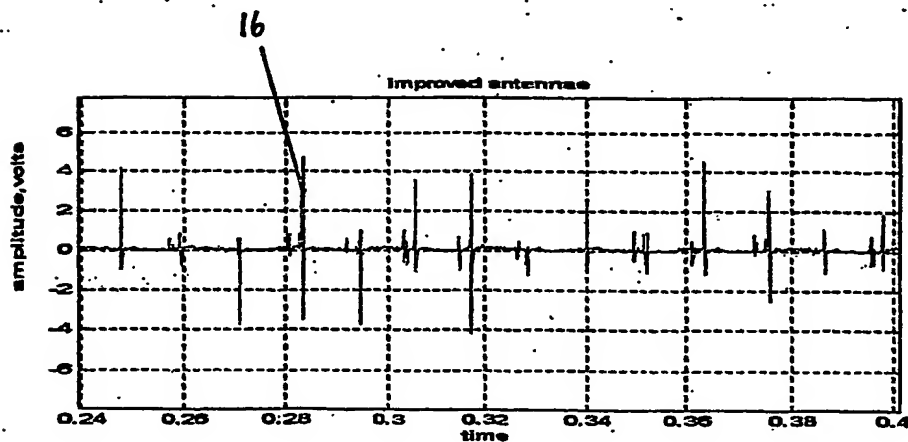
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FIGURE 2FIGURE 3

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(a)



(b)

FIGURE 4

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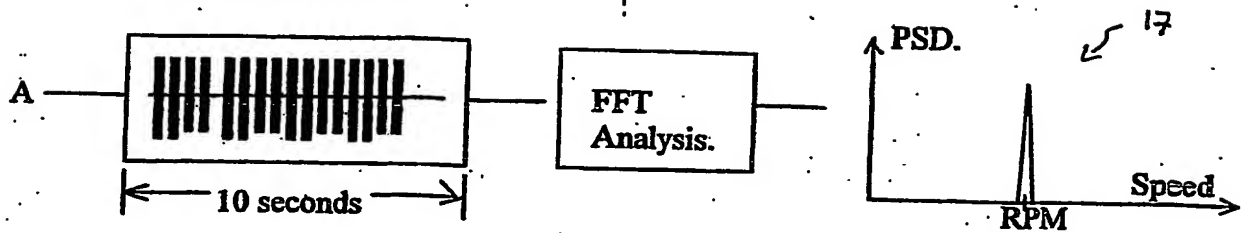


Figure 5

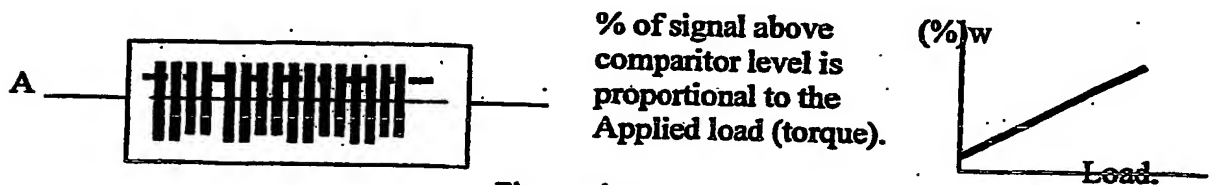


Figure 6(a)

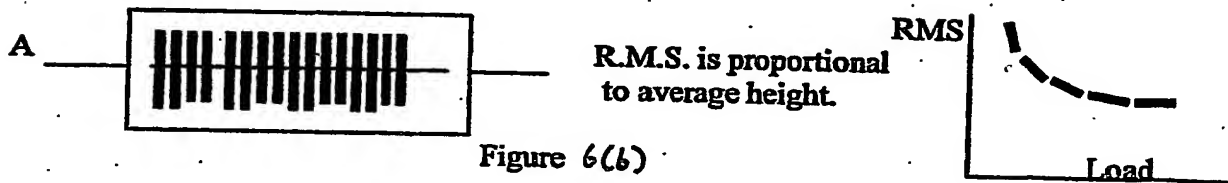


Figure 6(b)

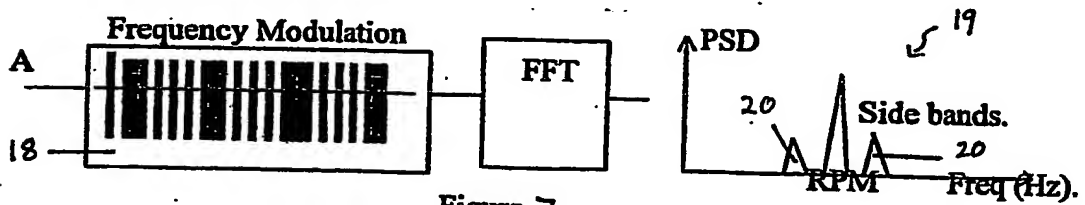


Figure 7

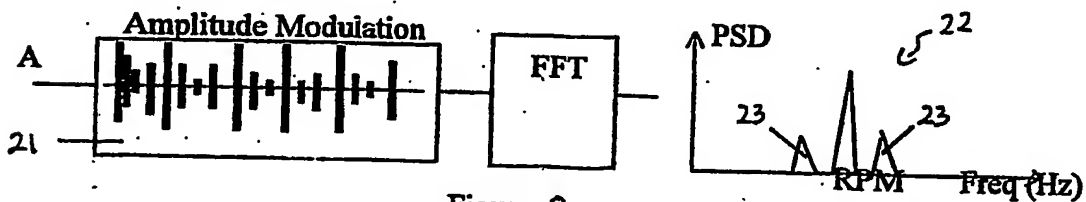


Figure 8

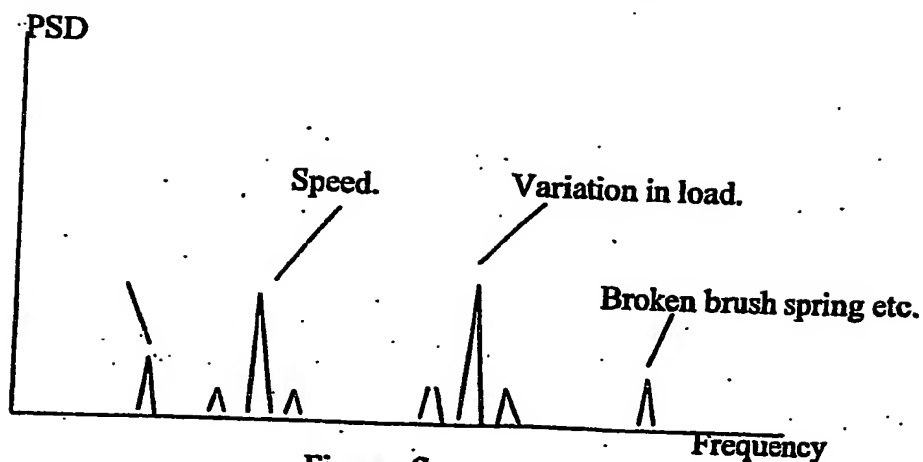


Figure 9

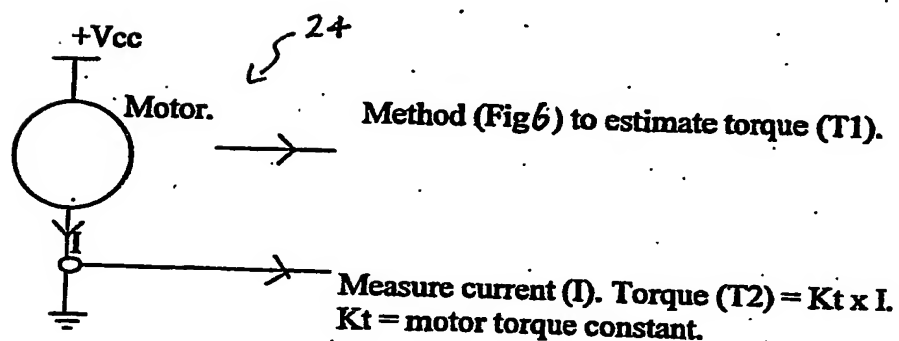


Figure 10

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